

THERMAL ENERGY DISSIPATION IN WAVE PROPAGATION OVER A NON-STRATIFIED MOVING MEDIUM

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ABSTRACT

From some years ago until now, is growing interest for to study of the impacts of any technical device on the environment. Therefore, is also interesting the estimation of the lost of thermal energy carried out in a sound wave crossing through a fluid medium. The perturbation is caused actually by an increase of heat at the environment of the sound wave energy. The aim of this paper is to detect the lost of energy of the wave assuming that the physical properties distributed in oscillating functions.

1. INTRODUCTION

Due to the growing interest to study the models of propagation of the sound and the environmental impacts in the different facets of the technique, we consider opportune to estimate which is the thermal interference on a medium when a sound crosses it. The mentioned interference consists on the increase of heating energy caused by the sound wave.

The objective of the present work is to determine the dissipation of thermal energy that takes place in the propagation of a sound wave through a fluid. We suppose a non stratified medium for the values of its physical properties and an oscillating function is also supposed for the properties of absorption and viscosity. The fundamental characteristic is the addition of the harmonic conjunction, in the sense that the evolution of a property of the medium generates the production of another with a certain and constant displacement factor. Three situations are analyzed: first a function cosine and sinus for the properties absorption and viscosity respectively; in second place, a function cosine and first harmonic for the absorption of the medium against a constant function of the viscosity; and in third place, a function cosine and first harmonic for the absorption of the medium front a function sinus of the viscosity. In this medium a plane wave sound spreads and its energy is invariable with regard to the time.

2. PROCEDURE OF CALCULATION

Starting from the equation that expresses the variation of the energy density of a wave in a medium with gradient of speed,

$$\frac{\partial W_r}{\partial t} = -\frac{\partial(W_r U_i)}{\partial x_i} - \frac{k_j I_i}{w_r} \frac{\partial v_j}{\partial x_i} \quad (1)$$

where, W_r is the energy of the wave, U_i is the wave group speed from the relative to the flow of the local means, k_j is the wavenumber according to the address of propagation of the wave, I_i is the density of energy flow of the medium according to a perpendicular direction to the propagation of the wave, w_r is the relative angular frequency to the local speed of the medium, and v_j is the speed of the medium through which the wave moves. The first term of the second member of the equation (1) represents the transport of the energy from the wave at the relative group speed to the local flow of the medium and the second term represents the energy exchange with the medium. A simple relationship exists among the absolute frequency of the oscillations that take place in a fixed point of the space and the relative frequency of the oscillations that take place in a point that moves with the medium speed v_j ,

$$w_r = w - k_j v_j \quad (2)$$

We call x_i the perpendicular axis to the direction of propagation of the wave (axis x_j). We determine the variation of the equation (2) regarding the axis c ,

$$\frac{\partial w_r}{\partial x_i} = \frac{\partial w}{\partial x_i} - k_j \frac{\partial v_j}{\partial x_i} \quad (3)$$

The elastic mediums are not perfect, and due internal frictions exist to their viscosity \mathbf{n} that cause that part of the energy of the wave gets lost in form of heat. The wave is muffled in its propagation, being said that the medium presents absorption. It is supposed that the medium presents a coefficient of absorption \mathbf{a} that comes given for,

$$\mathbf{a} = A w^2 \cos(B x_i) \quad (4)$$

being constant A and B ; x_i the distance in the direction of the propagation and w the angular frequency of the wave. The cinematic viscosity \mathbf{n} of the medium has of equation,

$$\mathbf{n} = C \text{sen}(D x_i) \quad (5)$$

where C and D are constant. The following relationship exists between the coefficient of absorption and the viscosity,

$$\mathbf{a} = \frac{2 \mathbf{n} w^2}{3 c^3} \quad (6)$$

If we get w of (6) and it is substituted in (3), and also the second term of (3) is substituted in the equation (1), it is obtained,

$$\frac{\partial W_r}{\partial t} = -\frac{\partial(W_r U_i)}{\partial x_i} + \frac{I_i}{w_r} \left[\frac{\partial w_r}{\partial x_i} - \frac{\partial}{\partial x_i} \left(\frac{3 \mathbf{a} c^3}{2 \mathbf{n}} \right)^{\frac{1}{2}} \right] \quad (7)$$

$$D(n, x) = -\frac{I_i}{w_r} \frac{\partial}{\partial x_i} \left(\frac{3 a c^3}{2 n} \right)^{\frac{1}{2}} \quad (8)$$

3. RESULTS

In this section are shown the variations of vanished thermal energy in function of the distance traveled in the axis x_i and in function of the absolute frequency of the wave. Those two variations are analyzed for different values of the constants mentioned in the paragraph previous A, B, C, D regarding the equations (4) and (5). It is considered that they are the same the densities of flow of the wave ($W_r c$) and of the medium I_i .

In the figures 1 and 2 the energy dissipation is represented in the case of functions harmonic displacement factor $p/2$. Two alternatives are shown as for values of coefficients of the equations (4) and (5).

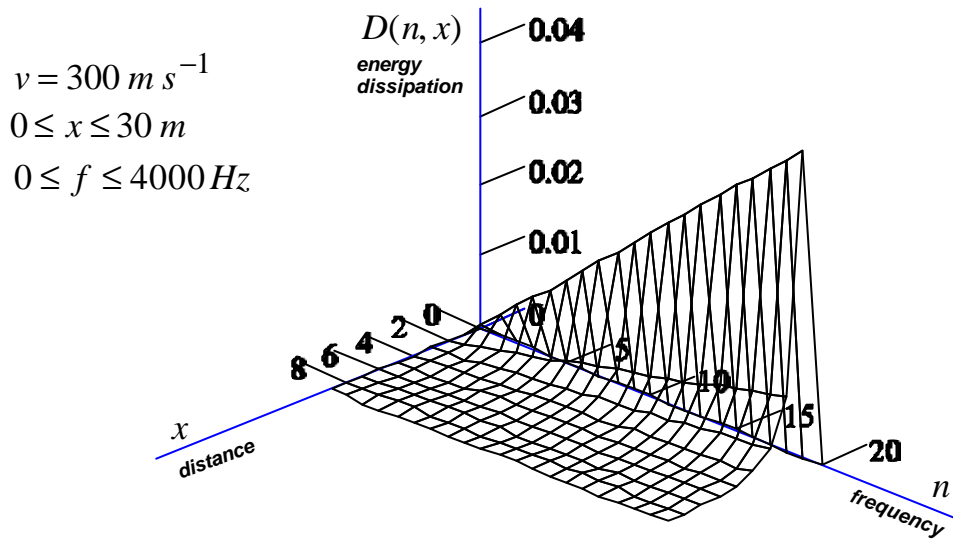


Fig. 1 Dissipation of the sound wave energy in function of the frequency and distance according to the propagation address. Speed of the medium is 300 m s^{-1} . Value of the coefficients A, B, C, D similar to 100.

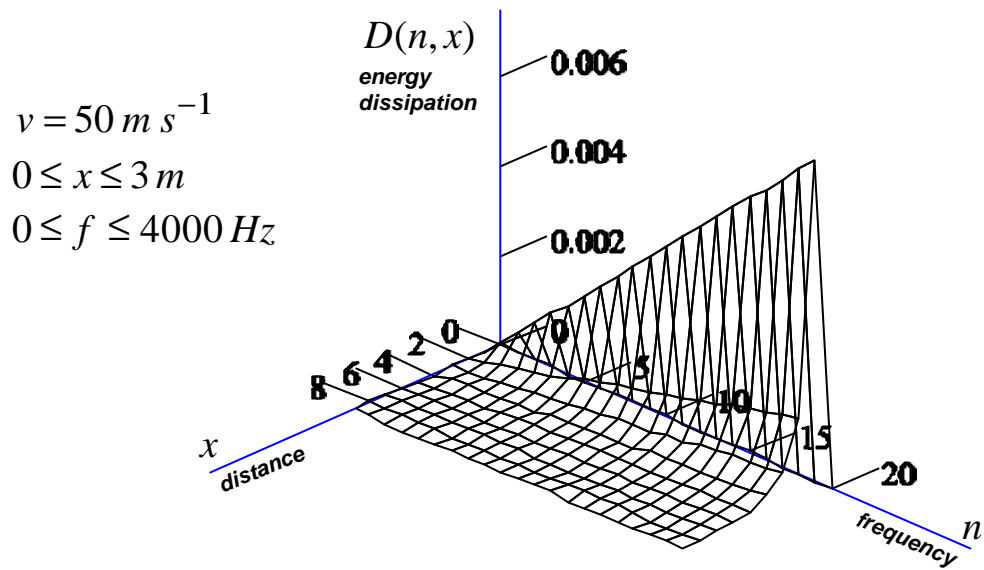


Fig. 2 Dissipation of the sound wave energy in function of the frequency and distance according to the propagation address. Medium speed is 50 m s^{-1} . Value of the coefficients A , B , C , D similar to 100.

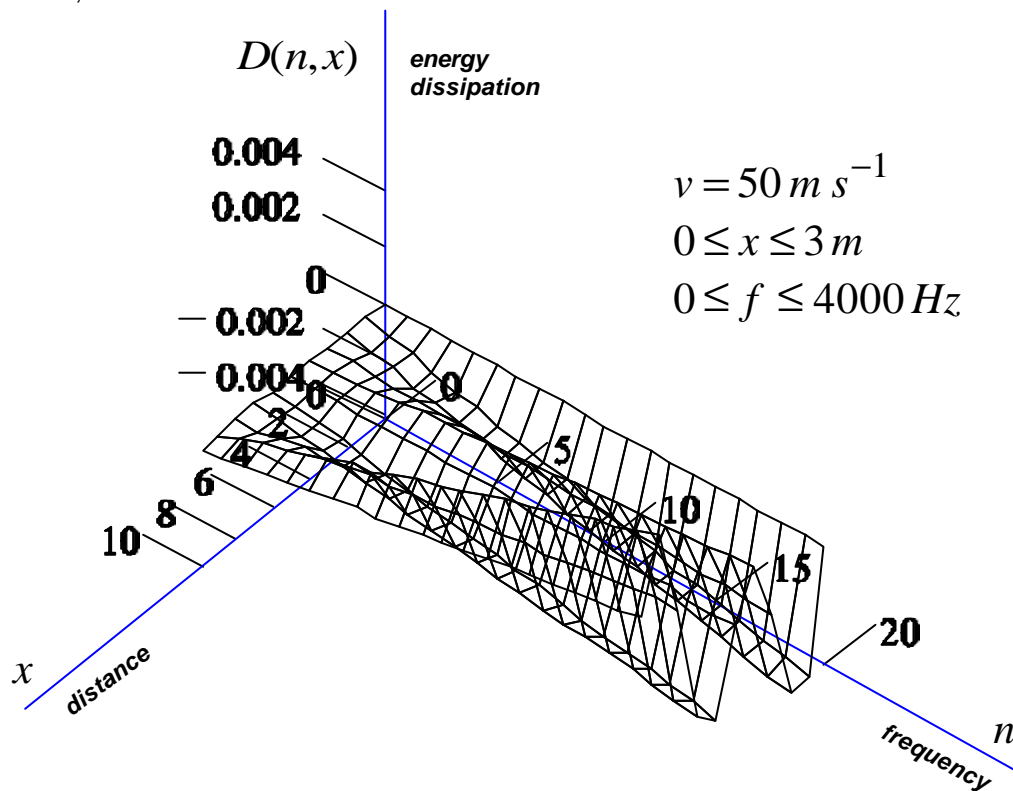


Fig. 3. Dissipation of the energy of the sound wave in function of the frequency and distance according to the propagation address. Speed of the medium is 50 m s^{-1} .

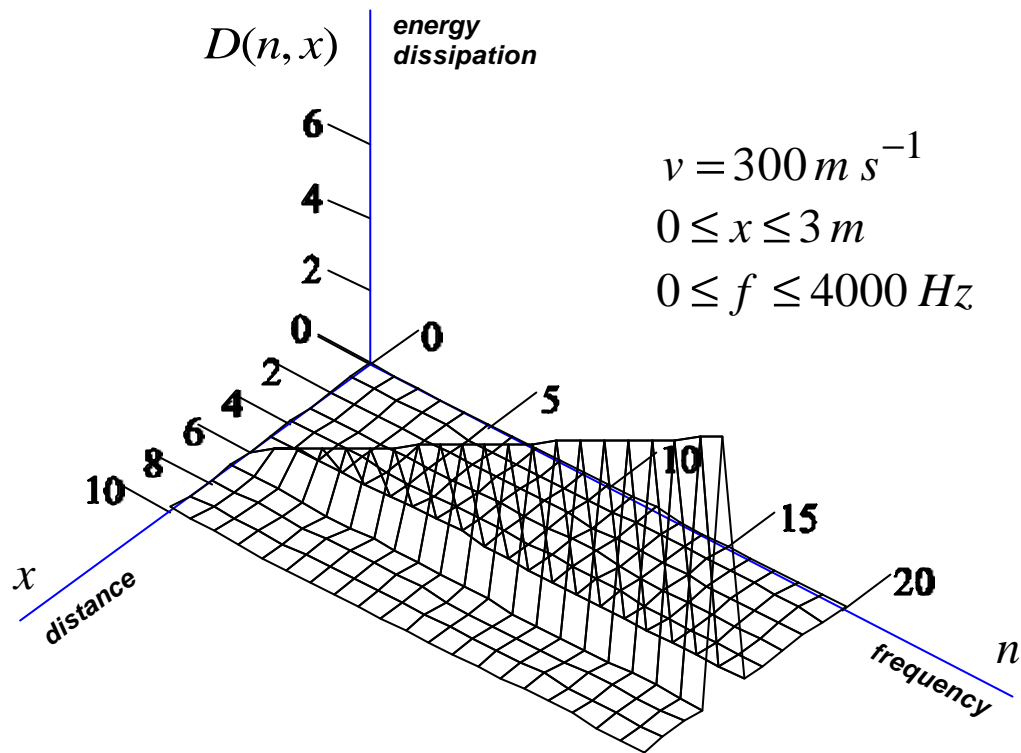


Fig. 4. Dissipation of the energy of the sound wave in function of the frequency and distance according to the propagation address. Speed of the medium is 300 m s^{-1} . In this case the range of the distance is from 0 to 3 m .

In the figures 3 and 4 are shown the energy dissipations of the wave considering a variation of the properties of the whole medium according to a combination of the function fundamental cosine and first harmonic. Two alternative cases are presented according to the speeds of the medium.

In the figures 5 and 6 the energy dissipations are represented in the supposition of one of function cosine and first harmonic for the property absorption of the medium and function sinus for property of viscosity.

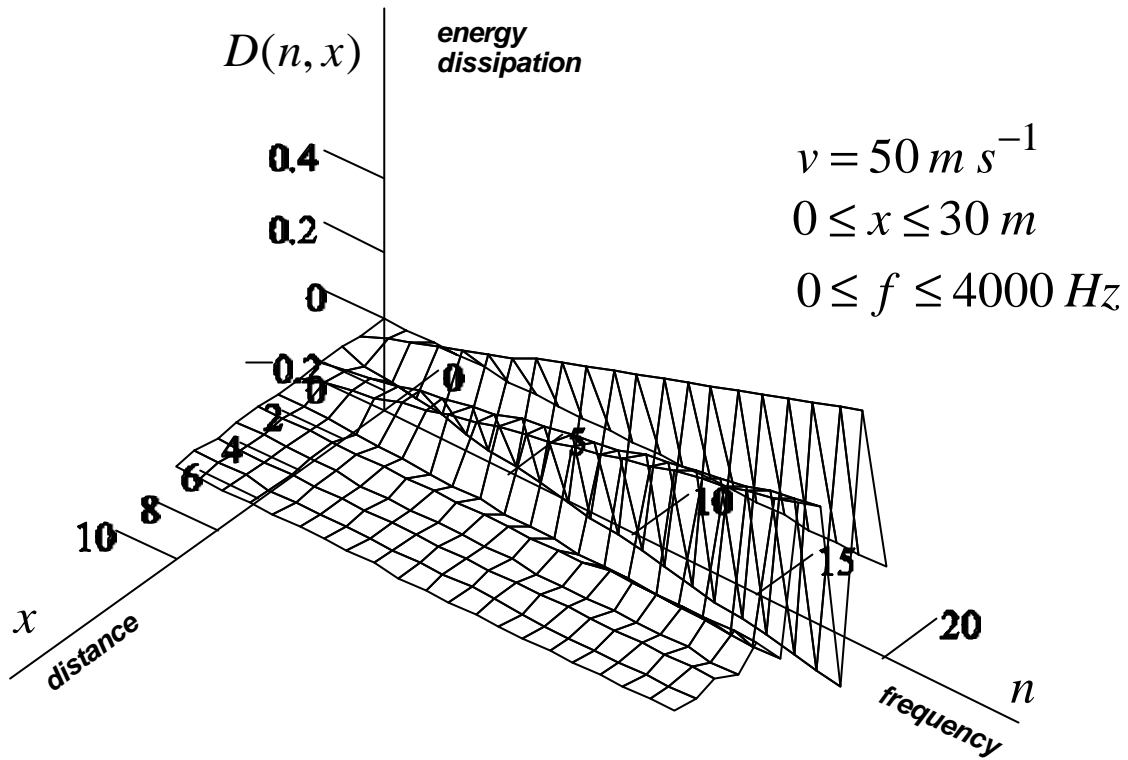


Fig. 5 Speed of the medium 50 m s^{-1} . The range of the distance is from 0 to 30 m .

4. CONCLUSIONS

In the figures 1 and 2 bigger dissipation of the energy is observed from the wave at high speeds of medium and frequencies. The figures 3 and 4 show some oscillations in the function dissipation. The negative values are discarded to lack physical sense. To bigger speed of the means the dissipation is bigger but it presents a graphic surface fewer perturbed.

In the figures 5 and 6 a contrary result is perceived, to low speed the dissipation of energy of the sound wave is superior regarding a high speed of the medium. However, the form of the graphic surface presents bigger interferences at high speeds.

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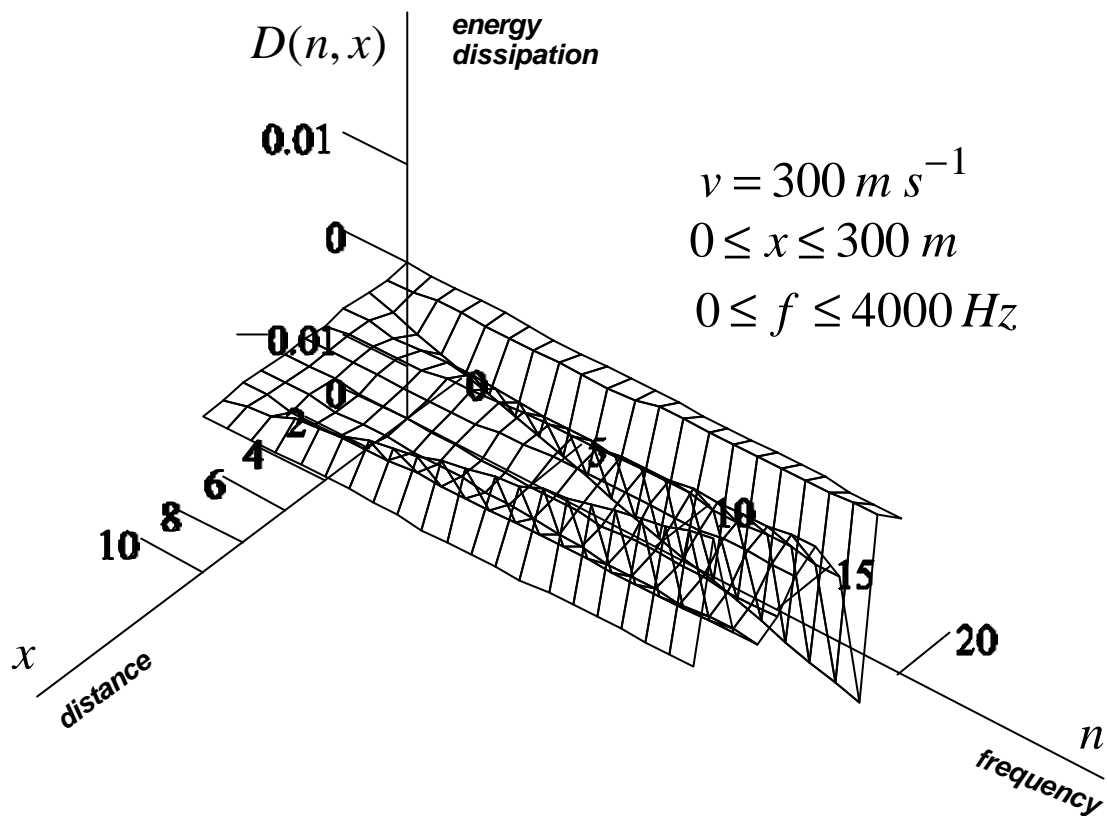


Fig. 6 Speed of the means 300 m-s-1. The range of the distance is from 0 to 300 m .

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